(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : 0 481 797 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number : 91309609.5

(22) Date of filing : 17.10.91

(51) Int. Cl.^{5} : B41J 2/07

(30) Priority : 18.10.90 US 599644

(43) Date of publication of application : 22.04.92 Bulletin 92/17

(84) Designated Contracting States : BE CH DE DK FR GB IT LI NL

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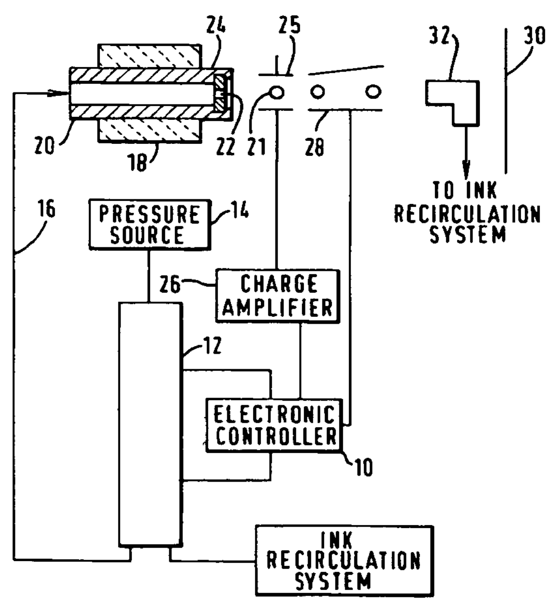
(54) Character height control for drop markers.

(57) A drop marker includes a chamber (12) for electrically conductive marking ink, a pressure source (14) for creating a stream of the ink, and a print head (18) for breaking this stream of ink into drops (21). Charge electrodes (25) impart an electric charge on selected drops, and deflection electrodes (28) create an electric field to control the flight path of the charged drops to mark characters on a substrate (30). The characters are maintained at a desired height by an electronic controller (10) in the form of a system microprocessor which measures a flow parameter of the ink and adjusts the deflection of the ink drops in response to the measured change in the flow parameter. Deflection of the ink drops is adjusted by modifying the deflection voltage applied to deflection electrodes (28) and/or by modifying the electric charge imparted to the selected drops by a charge amplifier (26).

FIG.1



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The present invention relates generally to the field of drop marking, including ink jet printing, and more particularly to controlling the height of characters produced thereby.

Drop markers commonly utilise charge deflection printers of a type known in the art. Such known printers employ a piezoelectric element to break a constant stream of electrically conductive marking fluid, such as ink, into uniform drops. The drops are then electrically charged by charge means in the form of charging electrodes. The charged drops travel through an electric field created by a deflection electrode means. The influence of the deflection field on the charged drops alters their flight path.

Most drop markers employ a pressurized distribution system, for creating a stream of marking fluid from a supply chamber to a nozzle, and a collection reservoir for capturing drops not intended to mark a target. The operation of most drop markers is controlled by a system microprocessor.

Use of a control system to maintain a constant ink flow rate in ink jet systems is known in the art. Examples of such control systems are shown in U.S. Patent No. 4,555,712 (hereinafter referred to as "the Arway patent") and U.S. Patent No. 4,827,280 (hereinafter referred to as "the Stamer patent"). These control systems measure the flow rate of the marking fluid in the system and alter variables, such as the amount of solvent contained in the ink, or the magnitude of pressure applied to force ink through the system, or ink temperature, to keep the flow rate at a predetermined value.

Even with these control systems, a problem has been the inability to control the height of printed characters with sufficient accuracy. The height of printed characters has been found to vary due to a number of environmental factors, such as operating temperature of the printer and ink solvent evaporation. The prior art control systems lack the ability to compensate fully for variations in character height resulting from these factors.

Some attempts have been made to maintain constant character height for charge deflection printers by making adjustments when the printer is initially set up or during maintenance. One such scheme is disclosed in U.S. Patent 4,847,631 (hereinafter referred to as "the Naruse patent") in which a user sets a predetermined character height when the print head is replaced. The Naruse patent discloses a relationship between the stream velocity of marking fluid and character height. Naruse, however, does not compensate for changes in character height over time due to the external factors previously described, principally changes in operating temperature.

A marking device capable of monitoring and adjusting the character height on an ongoing basis is desirable as it enhances marking quality. It is an object of the present invention to provide a control system capable of automatically adjusting the height of characters marked on a substrate by a drop marker, such as an ink jet printer, of the type in which a stream of electrically conductive marking fluid is created and is subsequently broken into drops, a charge means imparts an electric charge on selected drops, and a deflection electrode means creates an electric field to control the flight path of the charged drops dependant on a deflection voltage applied to the deflection electrode means.

According to one aspect of the invention the characters marked on the substrate are maintained at a desired height by a control means which measures a flow parameter of the marking fluid and adjusts the deflection of the charged drops in response to such measured changes in the flow parameter of the marking fluid.

The control means may be arranged to adjust the deflection of the charged drops by modifying the deflection voltage to the deflection electrode means. In this case the control means may include a processor for altering the deflection voltage according to a linear approximation of empirically determined data relating the flow parameter to the deflection voltage. Alternatively the control means may include a memory means having a look-up table relating the deflection voltage to a corresponding flow parameter, and the control means is arranged to adjust the deflection voltage responsive to measured changes in the flow parameter in accordance with the corresponding deflection voltage value in the look-up table. Alternatively the flow parameter may be the velocity (V_s) of the stream, and the control means includes a processor for adjusting the deflection voltage (HV) according to an approximation of the relationship:-

$$HV = K_2.(V_s)^n$$

where K_2 represents a constant for a given drop marker and n is a number from 2 to 3. Alternatively the flow parameter may be the flight time (T_{FLT}) of the drops over a given distance, and the control means includes a processor for adjusting the deflection voltage (HV) according to an approximation of the relationship:-

$$HV = K_3.\frac{1}{{T_{FLT}}^N}$$

where K_3 represents a constant for a given drop marker and n is a number from 2 to 3.

The control means may alternatively or additionally be arranged to adjust the deflection of the charged drops by modifying the electric charge imparted to the selected drops by the charge means. In this case the charge means may include a charge amplifier controlled by the control means to adjust the electric charge. The control means may include a processor for altering the gain of the charge amplifier according to a linear approximation of empirically determined data relating the flow parameter to the gain of the charge amplifier.

Alternatively the control means may include a memory means having a look-up table relating the gain of the charge amplifier to a corresponding flow parameter, and the control means is arranged to adjust the gain of the charge amplifier responsive to measured changes in the flow parameter in accordance with the corresponding gain value in the look-up table. Alternatively the flow parameter may be the velocity (V_S) of the stream, and the control means includes a processor for adjusting the gain (G_Y) of the charge amplifier according to an approximation of the relationship:-

$$G_Y = K_4.V_S^n$$

where K_4 represents a constant for a given drop marker and n is a number from 2 to 3. Alternatively the flow parameter may be the flight time (T_{FLT}) of the drops over a given distance, and the control means includes a processor for adjusting the gain (G_Y) of the charge amplifier according to an approximation of the relationship:-

$$G_Y = K_5.\frac{1}{T_{FLT}^n}$$

where K_5 represents a constant for a given drop marker and n is a number from 2 to 3.

It is also an object of the present invention to provide a method of automatically adjusting the height of characters marked on a substrate by a method of the type in which a stream of charged drops of electrically conductive marking fluid is projected towards the substrate, and an electric field is varied to deflect the charged drops to form the characters.

According to this aspect of the invention the characters are maintained at a desired height by measuring a flow parameter of the fluid, and by adjusting the deflection of the charged drops in response to changes in the flow parameter. The deflection of the charged drops may be adjusted by varying the electrical field in response to changes in the flow parameter. Alternatively or additionally the deflection of the charged drops may be adjusted by varying the charge on the drops in response to changes in the flow parameter.

The invention provides a control system which has the capability of minimizing the influence on character height of external factors such as variations in printer operating temperature, because such external factors effect the flow parameters of the marking fluid. Any flow parameter of the marking fluid, for instance flow velocity or flight time of the drops, is related to the viscosity of the marking fluid, which in turn is related to its temperature.

The invention also provides a control system capable of operation without regard to changes in the physical characteristics of the marking fluid, because such changes which could affect character height, for instance solvent evaporation, also effect its viscosity which, as stated above, is related to the measured flow parameter of the marking fluid.

The present invention provides dynamic adjustment of deflection sensitivity in drop markers, such as ink jet marking devices. It exploits the relationship between the voltage applied to the deflection electrodes of a drop marker and the height of the characters produced by periodically adjusting the deflection voltage dependent on measured changes in a flow parameter of the marking fluid, such as flow rate of the fluid, or flight time of drops of marking fluid to a print substrate. Alternatively, or additionally, it exploits the relationship between the charge applied to the drops and the deflection achieved by the voltage applied to the deflection electrodes, by periodically adjusting a charge amplifier to scale the charge applied to the drops dependent on measured changes in a flow parameter of the marking fluid, thereby controlling character height.

Unlike character height control systems found in the prior art, such as the Naruse patent, the present invention determines a flow parameter, such as stream velocity and/or drop flight time, and periodically alters the deflection voltage and/or charge amplifier gain during printer operation. Thus, character height is kept within optimum limits notwithstanding changes in the printer operating environment that would otherwise adversely affect uniformity of character height.

The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:-

Figure 1 is a diagram of an ink jet printer illustrating features of the present invention;

Figure 2 is a diagram showing the relationship between the stream velocity or flight time of an ink drop and character height under simplifying assumptions;

Figure 3 is a diagram similar to Figure 2 showing the most and least significantly deflected drops for forming a given character;

Figure 4 is a software flow diagram for implementing the control function of the present invention, and

Figure 5 is a graph showing the empirically determined relationship between deflection voltage and flow time for achieving constant character height.

With reference to Figure 1, an electronic controller 10, in the form of a system microprocessor, is configured to measure the flow rate or flow time of electrically conductive ink, or other marking fluid, through an ink chamber 12.

As will be apparent to one having ordinary skill in the art, flow rate and flow time are inversely proportional to one another. Thus, either may be calculated if the other is known, provided the volume of chamber 12 is

also known.

Ink is forced through the system by a pressure source 14 which is connected to the top of chamber 12 and constitutes a means for creating a stream of the ink. Ink from the bottom of the chamber 12 is carried via a flexible conduit 16 to a print head 18 which has a vibrating piezoelectric element 20 for breaking the stream of ink into drops 21 as they leave an orifice 22 in a nozzle 24. As the drops 21 exit the nozzle, they pass a charge means in the form of a charge electrode 25 where they receive an electric charge. The magnitude of the charge is set by a charge amplifier 16 under control of the electronic controller 10. A set of deflection electrodes 28 is supplied with a high voltage to generate an electric field to act on the charged drops 21, causing them to be deflected to a desired location on the substrate. Drops that are not projected onto the substrate are caught by a collector 32 for subsequent reuse. The voltage on the deflection electrodes 28, and/or the gain of the charge amplifier 26, may be adjusted by the electronic controller 10 in response to measured changes in a flow parameter of the ink.

The teachings of the present invention may be practiced by measuring any convenient flow parameter of the ink, such as flow time or flow rate of the ink from the ink chamber 12 or through the conduit 16, or the flight time of the drops 21. For convenience, each of these various parameters is referred to collectively herein as a "flow parameter." The Arway patent discloses one method for mesuring flow rate, however any flow parameter may be measured by any suitable method. As will be described hereinafter, any one of the flow parameters may be used to set constant character height by adjusting the deflection voltage on the deflection electrodes 28, and/or the gain of the charge amplifier 26. Charge amplifier gain and deflection voltage are each referred to collectively herein as an "adjustable parameter."

The present invention exploits the relationship between a flow parameter and an adjustable parameter for the purpose of maintaining constant character height. As noted previously, any of the various flow parameters may be used to control the value of either of the two adjustable parameters. For purposes of example, the following discussion concentrates on the use of the flow rate to adjust deflection voltage. It will be readily apparent to one of ordinary skill in the art that this example can be easily modified to develop the relationships between any measured flow parameter and either adjustable parameter.

Figure 2 illustrates the flight path 34 of an ink drop 21 as it passes through the electric field created by the deflection electrodes 28. The ink drops are deposited on a substrate 30, such as a sheet of paper. The flight path an ink drop would follow without the influence of the deflection field is shown by dashed line 38. V_S represents the stream velocity of the marking fluid. V_S is directly proportional to the flow rate, and can, therefore, be calculated by the electronic controller 10 after measurement of the flow rate. The deflection d is induced by the action of the deflection electrodes on a given drop of marking fluid. The deflection d comprises two components, the deflection d_1 while the ink drop is traveling through the deflection field, and the deflection d_2 after the drop exits the deflection field. Therefore, deflection d is the sum of deflections d_1 and $_2$. L_1 is the length of the deflection field, and L_2 is the length from the end of the deflection field to the substrate 30. Similarly, the time the ink drop spends traveling through the deflection field is designated T_1 while the time spent traveling to the substrate 30 after exiting the deflection field is designated T_2. The flight time T of each drop 21 is the sum of T_1 and T_2.

For simplicity and ease of understanding the present invention, it is convenient to assume constant drop mass, charge and stream velocity, and to ignore charge interactions between drops. Under these assumptions, the following relationships between the various parameters may be expressed:-

$$d = \frac{1}{2} aT_1^2 + aT_1T_2 \quad [1]$$

Drop acceleration a is generally represented as follows:-

$$a = \frac{YE}{m} \quad [2]$$

where E is the magnitude of the electric field created by the deflection electrodes 28, the magnitude of the charge imparted to the ink drop by the charge amplifier 26 is Y, and the mass of the ink drop is m.

The electric field magnitude E is proportional to the voltage across the deflection electrodes 28 and will vary depending on the exact dimensions and spacing of these electrodes. For a given set of electrodes, this relationship can be readily computed.

The following equations express the time T_1 spent by an ink drop traveling at velocity V_S in the deflection field and the time T_2 after the drop exits the deflection field until it impacts the substrate:-

$$T_1 = \frac{L_1}{V_s} \quad [3]$$

$$T_2 = \frac{L_2}{V_s} \quad [4]$$

Substituting equations [3] and [4] into equation [1] yield the following equation for character height d:-

$$d = \frac{a}{2} \cdot \frac{L_1^2}{V_s^2} + \frac{a.L_1L_2}{V_s^2} \qquad [5]$$

Simplifying further:-

$$d = \frac{a}{V_s^2} . L_1 \left(\frac{L_1}{2} + L_2\right) \qquad [6]$$

As L_1 and L_2 are constant for a given machine, then let:-

$$K_1 = L_1\left(\frac{L_1}{2} + L_2\right) \qquad [7]$$

Thus, substituting equation [7] into equation (6):-

$$d = \frac{aK_1}{V_s^2} \qquad [8]$$

As can be readily seen from equation 8, the above relationship indicates that character height d is directly proportional to acceleration a induced on the ink drop, which is in turn proportional to the voltage supplied to the deflection electrodes of the drop marker. Under the simplifying assumptions as stated above, the character height d also varies inversely with the square of stream velocity V_S. Therefore, uniform character height can be maintained, as V_S changes, by determining V_S and adjusting the deflection electrode voltage level to maintain the electric field strength so that acceleration a is adjusted proportionally to the square of V_S.

Rearranging equation [8] and assuming constant deflection d, then

$$a = \frac{d}{K_1} . V_s^2 \qquad [9]$$

But from equation [2]

$$a = \frac{Y}{m}.E = \frac{Y}{m}.\frac{HV}{D_G} \qquad [10]$$

where HV is the deflection voltage and D_G is the deflection electrode gap distance.
Then combining equations [9] and [10] to eliminate a gives:-

$$\frac{Y}{m}.\frac{HV}{D_G} = \frac{d}{K_1}.V_S^2 \qquad [11]$$

Rearranging equation [11] gives:-

$$HV = \frac{m.D_G.d}{Y\ K_1} . V_s^2 \qquad [12]$$

Since all terms on the right hand side of equation [12], apart from V_S, can be assumed constant, then HV must vary in proportion to V_S^2 to maintain constant deflection, d.

$$\text{If } K_2 = \frac{m.D_G.d}{Y\ K_1}$$

then $HV = K_2.V_S^2$ [13]
represents the proper relationship between the deflection voltage and stream velocity.

In a preferred embodiment of the present invention, the electronic controller 10 exploits these relationships by determining the stream velocity V_S and adjusting the voltage across the deflection electrodes 28 to maintain constant character height.

Empirical test data indicates that character height actually varies to a greater extent than by the square of V_S. This is caused in part by the fact that the simplifying assumptions made for the foregoing analysis do not prevail in actual printer operation. For example, nozzle drive frequency remains constant even though V_S changes over time. The result is that drop mass changes, altering the relationship between character height and stream velocity. Other contributing factors are variation in drop charge, mutual repulsion of charged drops in flight and aerodynamic effects on the flight of drops. The resulting relationship in an actual printer may be expressed as:

$$HV = K_2.V_S^n \quad [14]$$

where n is a number from 2 to 3, for example 2.5.

These effects can be compensated by empirically measuring the relationship between the flow parameter being measured to control character height (for example, flow time, flow rate or flight time), and the adjustable parameter used to adjust character height (for example, deflection voltage or charge amplifier gain) for constant character height.

Figure 5 shows an example of empirical data relating the measured flow parameter, that is in this case flow time, to the adjusted parameter, deflection voltage. Furthermore, as will be described hereinafter, a linear approximation of this relationship may be employed to set the value of the adjusted parameter over a realistic operating range.

It should be noted that the foregoing analysis allows uniformity of character height to be maintained regardless of variation in external operating conditions, such as temperature, which produce a variation in the flow parameter. It will be apparent that the relationship between flow rate V_S, flow time and total flight time $T_1 + T_2$ is such that only one of these flow parameters needs to be known to allow determination of a relationship for constant character height that can be employed by the present invention (see equations [3] and [4]). Furthermore, that the flight time of a drop between two fixed points within the print head is proportional to total flight time. Therefore, this flight time, which is more convenient to measure, is also suitable as the measured flow parameter.

If flight time is the measured parameter, L_{FLT} is the distance over which flight time is measured and T_{FLT} is the flight time over that distance, then:

$$V_s = \frac{L_{FLT}}{T_{FLT}}$$

Substituting this into equation [13], then:-

$$HV = K_2.\frac{L_{FLT}^{\ 2}}{T_{FLT}^{\ 2}} \quad [15]$$

Equation [15] can be rearranged as:

$$HV = [K_2.L_{FLT}^2].\frac{1}{T_{FLT}^2} \quad [16]$$

Since all the terms in the square brackets are constant, HV must vary in proportion to the inverse of T_{FLT}^2 to maintain constant deflection, d.

If $K_3 = K_2\, L_{FLT}^2$, then:-

$$HV = K_3.\frac{1}{(T_{FLT})^2} \quad [17]$$

Equation [17] is of course subject to the simplifying assumptions stated earlier. As stated earlier, the actual printer performance varies more strongly than the inverse of $T_{FLT}^{\ 2}$.

The more general case is:-

$$HV = K_3.\frac{1}{T_{FLT}^n} \quad [18]$$

where n is a number from 2 to 3.

If flow time is used instead of flight time, a different constant multiplier would be substituted for K_3, and flow time would be substituted for flight time.

Thus, for example, flow rate, flow time or flight time may be the measured flow parameter to practice the teachings of the present invention, depending on relative ease and/or expense of acquiring the measurement.

It will be appreciated that an analysis similar to the foregoing can be performed to demonstrate that the general teachings of the present invention may be employed to maintain constant character height by scaling

the gain of the charge amplifier 26 to modify the charge Y applied to the ink drops prior to their entry into the deflection field. Normally, a charging voltage V_Y is applied to the charge tunnel to cause a charge Y to be applied to the ink drop. The $Y = G_Y . V_Y$ where G_Y represents the transfer function from voltage to charge. If this multiplying factor G_Y is increased or decreased, that is, scaled up or down, so will subsequent charge values applied to subsequent ink drops.

Using a similar derivation as [9] through [13] above, Then:-

$$a = \frac{Y}{m}.E = G_Y.V_Y.\frac{E}{m} \quad [19]$$

and:-

$$G_y = \frac{m.d}{V_y.E.K_1} . V_s^2 \quad [20]$$

Since all terms on the right hand side of equation [20], apart from V_S, can be assumed constant, then the charge amplifier scaling factor G_Y, must vary proportionally to $(V_S)^2$ to maintain constant deflection, d.

$$\text{If } K_4 = \frac{m.d}{V_y.E.K_1}$$

then

$$G_Y = K_4.V_S^2 \quad [21]$$

The more general case is:-

$$G_Y = K_4.V_S^n$$

where n is a number from 2 to 3.

Using a similar derivation as [15] through [18] above,
Then:-

$$G_Y = K_5.\frac{1}{T_{FLT}^2}$$

The more general case being:-

$$G_Y = K_5.\frac{1}{T_{FLT}^n}$$

where n is a number from 2 to 3.

Figure 3 shows that the total character height d_{CH} is the difference between the deflection distance of the most deflected drop d_H for a given character, and the deflection of the least deflected drop d_L that is part of the same character. The teachings of the present invention are ultimately employed to maintain d_{CH} constant. This goal is accomplished by controlling the deflection distance of each individual drop forming a character because the amount of deflection is proportional to the magnitude of drop charge and the voltage across the deflection electrodes.

Figure 4 is a simplified flow diagram showing an algorithm suitable for use with a general purpose microprocessor for periodically determining one of the measured flow parameters previously described, and for using this information to control the adjustable parameter to maintain a desired character height. Assuming the automatic character height control feature is active, the user may select the desired character height for a given print job prior to operation of the drop marker. The algorithm can be executed periodically during printer operation or when the printer is idle. Experimental data demonstrates satisfactory results if the algorithm is executed at least every ten minutes during printer operation.

In operation, the system microprocessor 10 measures one flow parameter. The teachings of the Arway patent or Stamer patent may be employed for measuring the flow rate of the marking fluid. Alternatively, the microprocessor may measure the flight time of ink drops by, for example, detecting the time taken for the drops to travel a known distance. Similarly, the microprocessor may measure flow time of marking fluid in chamber 12. As previously described, the calculations of deflection voltage will differ only slightly, depending on which measured parameter is determined.

Next, the microprocessor determines the value of the adjustable parameter necessary to maintain constant character height for the measured parameter. The microprocessor may determine the value of the adjustable

parameter by employing one of three different methods.

In the first method, the microprocessor calculates the proper value of the adjustable parameter according to the mathematical relationships developed above.

In the second method, the microprocessor calculates the value of the adjustable parameter based on a mathematical approximation of empirically measured data relating one measured flow parameter to one of the adjustable parameters. As previously noted, acceptable uniformity of character height may be achieved by employing an approximation of the relationship between the measured flow parameter, rather than by calculating the corresponding value of the adjustable parameter. For example, the solid lines in Figure 5 show a best fit curve approximation of the relationship between flow time and deflection voltage in the range of deflection voltages between 3 kilovolts and 6 kilovolts, and flow times between sixty and seventy-five seconds.

The relationship between some combinations of measured flow parameter and adjustable parameter allows adjustment based on a linear approximation over certain ranges. The dashed lines in Figure 5 show a linear approximation of the empirical relationship between flow time and deflection voltage. The slope of this line may be determined from mathematical analysis of the empirical data. After the slope has been determined, the microprocessor may be programmed to calculate the new deflection voltage value using linear approximation after measuring the prevailing flow time.

An example of an algorithm suitable for calculating the new deflection voltage consists of initial measurement of the deflection voltage. This value is designated HV_{ref}. Next, the initial flow time T_{ref} is measured. The slope of the linear approximation of the relationship between flow time and deflection voltage, which has been determined previously from empirical data, is designated S. The actual flow time measured for a specific subsequent adjustment of the deflection voltage is designated T_{actual}. A short term average of a number of recent flow time measurements may be used for T_{actual}, depending on the desired accuracy in control of character height. HV_{actual} represents the calculated value of the deflection voltage required to maintain constant character height for the flow time T_{actual}. Under these conditions, the microprocessor will calculate the new deflection voltage HV_{actual} as follows:

$$HV_{actual} = HV_{ref} + S(T_{ref} - T_{actual}) \quad [22]$$

The calculated deflection voltage may be limited to minimum and maximum acceptable values in the event that the calculated value goes beyond the range over which the linear approximation is sufficiently accurate or goes beyond the range allowed for the head design.

In the third method, the microprocessor utilises a look-up table stored in system memory that relates a given measured flow parameter to the corresponding adjustable parameter. As will be apparent to one of ordinary skill in the art, data for the look-up table may be obtained using either of the first two methods.

Finally, the microprocessor sets the adjustable parameter to the level determined by method one, method two or method three. As previously noted, the microprocessor may be programmed to determine the measured flow parameter as often as desired for a specific application. Thus, character height is automatically controlled based on the prevailing flow rate, flow time or flight time, but without regard to external factors, such as operating temperature or any physical characteristic or a specific type of marking fluid.

Claims

1. A drop marker, for marking characters on a substrate, including means (12, 18) for creating a stream of electrically conductive marking fluid and for breaking this stream into drops (21), charge means (25) for imparting an electric charge on selected drops, and deflection electrode means (28) for creating an electric field to control the flight path (34) of the charged drops dependant on a deflection voltage applied to the deflection electrode means (28), characterised in that the characters marked on the substrate (30) are maintained at a desired height (d_{CH}) by a control means (10) which measures a flow parameter of the marking fluid and adjusts the deflection (d) of the charged drops (21) in response to such measured changes in the flow parameter of the marking fluid.

2. A drop marker, as in Claim 1, characterised in that the control means (10) is arranged to adjust the deflection (d) of the charged drops (21) by modifying the deflection voltage (HV) to the deflection electrode means (28).

3. A drop marker, as in Claim 2, characterised in that the control means (10) includes a processor for altering the deflection voltage according to a linear approximation of empirically determined data relating the flow parameter to the deflection voltage (HV).

4. A drop marker, as in Claim 2, characterised in that the control means (10) includes a memory means having a look-up table relating the deflection voltage (HV) to a corresponding flow parameter, and the control means is arranged to adjust the deflection voltage responsive to measured changes in the flow parameter in accordance with the corresponding deflection voltage value in the look-up table.

5. A drop marker, as in Claim 2, characterised in that the flow parameter is the velocity (V_S) of the stream, and the control means (10) includes a processor for adjusting the deflection voltage (HV) according to an approximation of the relationship:-

$$HV = K_2.(V_S)^n$$

where K_2 represents a constant for a given drop marker and n is a number from 2 to 3.

6. A drop marker, as in Claim 2, characterised in that the flow parameter is the flight time (T_{FLT}) of the drops over a given distance, and the control means (10) includes a processor for adjusting the deflection voltage (HV) according to an approximation of the relationship:-

$$HV = K_3.\frac{1}{T_{FLT}{}^n}$$

where K_3 represents a constant for a given drop marker and n is a number from 2 to 3.

7. A drop marker, as in any preceding claim, characterised in that the control means (10) is arranged to adjust the deflection (d) of the charged drops (21) by modifying the electric charge imparted to the selected drops by the charge means (25).

8. A drop marker, as in Claim 7, characterised in that the charge means (25) includes a charge amplifier (26) controlled by the control means (10) to adjust the electric charge.

9. A drop marker, as in Claim 8, characterised in that the control means (10) includes a processor for altering the gain (Gq) of the charge amplifier (26) according to a linear approximation of empirically determined data relating the flow parameter to the gain of the charge amplifier.

10. A drop marker, as in Claim 8, characterised in that the control means (10) includes a memory means having a look-up table relating the gain (Gq) of the charge amplifier (26) to a corresponding flow parameter, and the control means is arranged to adjust the gain (Gq) of the charge amplifier responsive to measured changes in the flow parameter in accordance with the corresponding gain value in the look-up table.

11. A drop marker, as in Claim 8, characterised in that the flow parameter is the velocity (V_S) of the stream, and the control means (10) includes a processor for adjusting the gain (G_Y) of the charge amplifier (26) according to an approximation of the relationship:-

$$G_Y = K_4.V_S{}^n$$

where K_4 represents a constant for a given drop marker and n is a number from 2 to 3.

12. A drop marker, as in Claim 8, characterised in that the flow parameter is the flight time (T_{FLT}) of the drops over a given distance, and the control means (10) includes a processor for adjusting the gain (G_Y) of the charge amplifier (26) according to an approximation of the relationship:-

$$G_Y = K_5.\frac{1}{T_{FLT}{}^n}$$

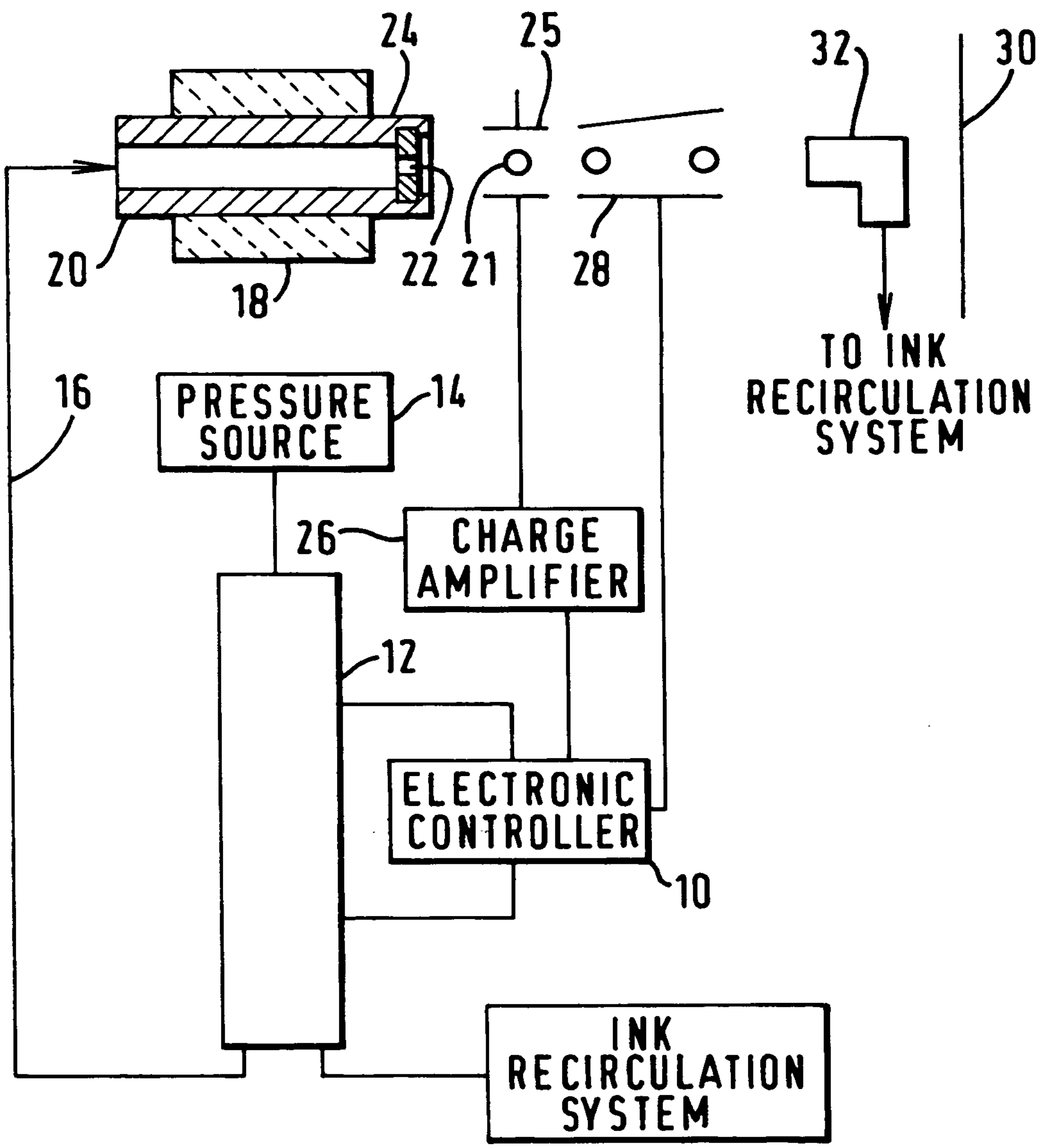
where K_5 represents a constant for a given drop marker and n is a number from 2 to 3.

13. A method of marking characters on a substrate including projecting a stream of charged drops of electrically conductive marking fluid towards the substrate, and varying an electric field to deflect the charged drops to form the characters, characterised in that the characters are maintained at a desired height (d_{ch}) by measuring a flow parameter of the fluid, and by adjusting the deflection (d) of the charged drops (21) in response to changes in the flow parameter.

14. A method, as in Claim 13, characterised in that the deflection (d) of the charged drops (21) is adjusted by varying the electrical field (28) in response to changes in the flow parameter.

15. A method, as in Claim 13 or 14, characterised in that the deflection (d) of the charged drops (21) is adjusted by varying the charge (25) on the drops in response to changes in the flow parameter.

FIG.1


24
25
32
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20
18
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28
TO INK
RECIRCULATION
SYSTEM
16
PRESSURE
SOURCE
14
26
CHARGE
AMPLIFIER
12
ELECTRONIC
CONTROLLER
10
INK
RECIRCULATION
SYSTEM

FIG. 2

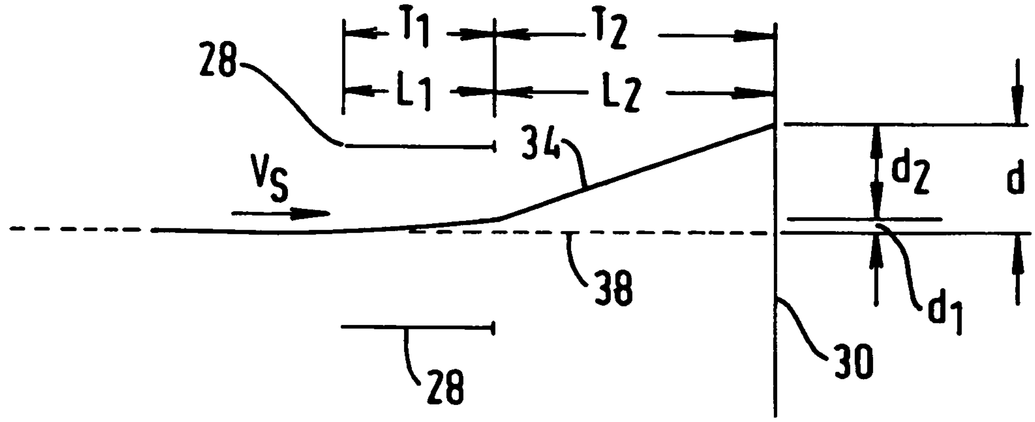
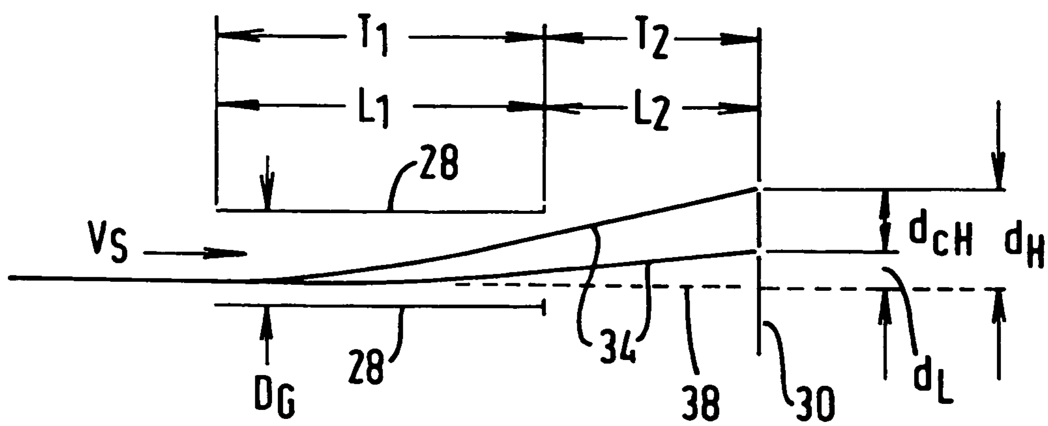

T1
T2
L1
L2
28
34
VS
d2
d
38
d1
30
28

FIG. 3


T1
T2
L1
L2
28
VS
dcH
dH
34
38
30
dL
DG
28

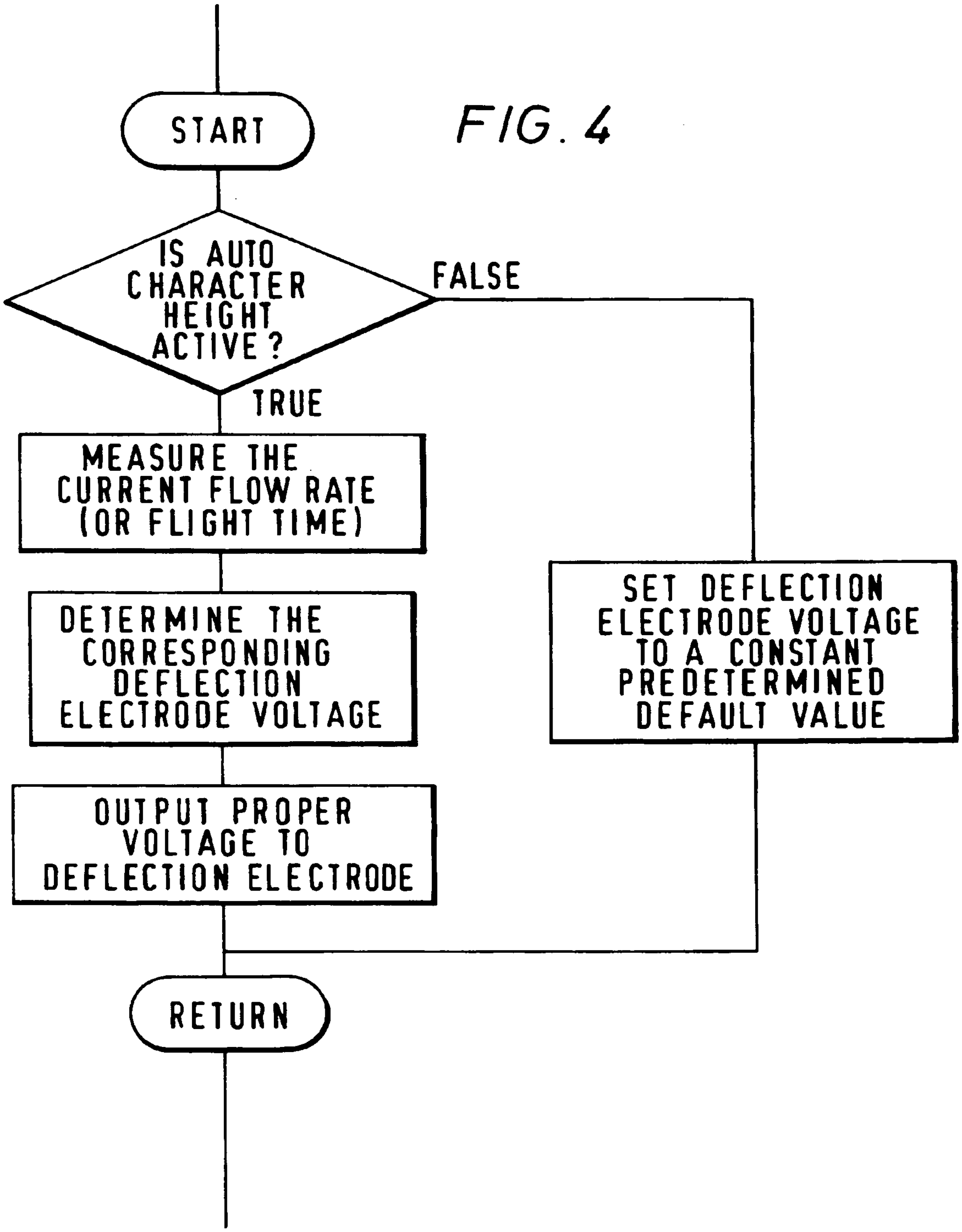
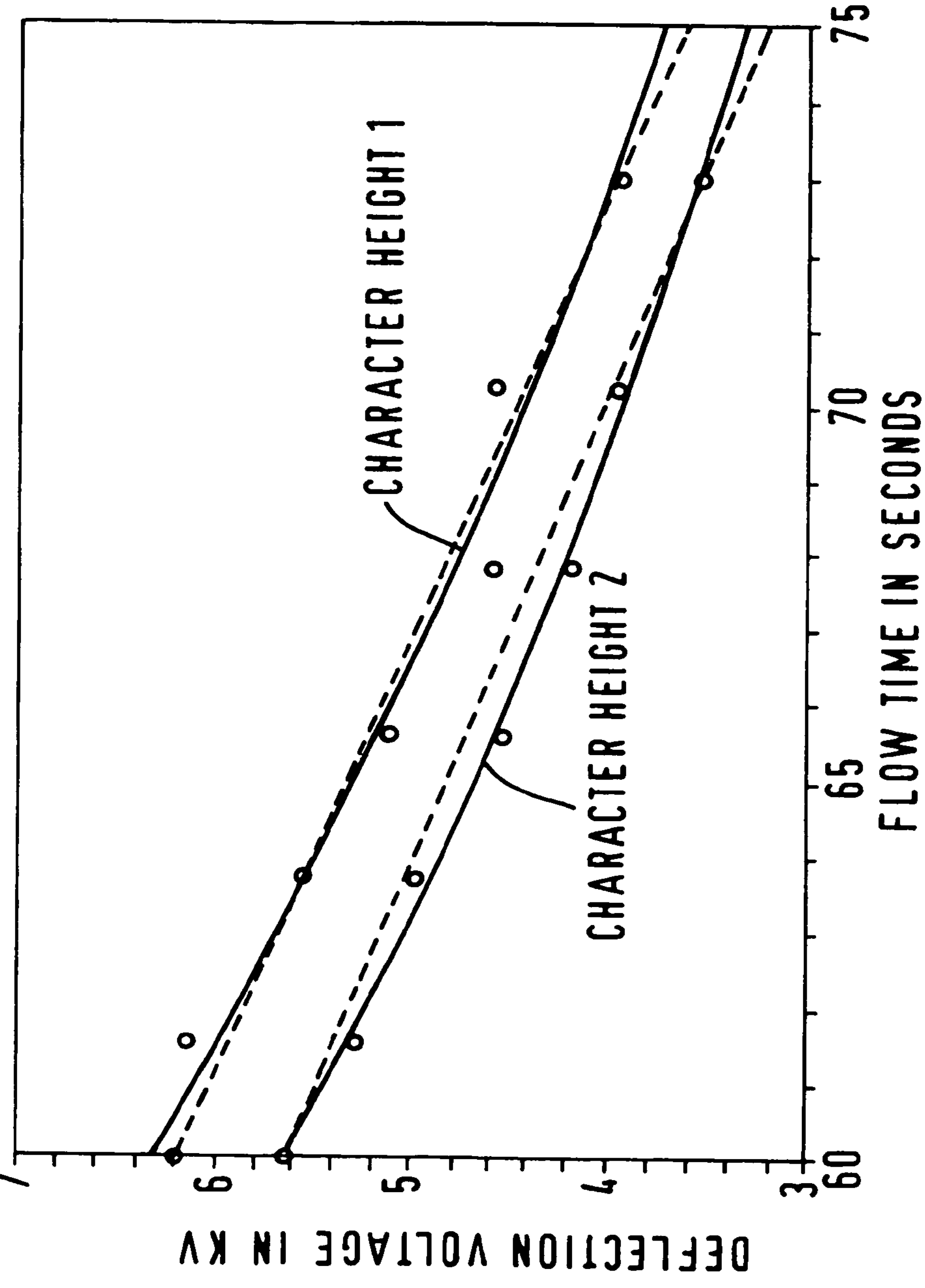

START
IS AUTO CHARACTER HEIGHT ACTIVE ?
FALSE
TRUE
MEASURE THE CURRENT FLOW RATE (OR FLIGHT TIME)
DETERMINE THE CORRESPONDING DEFLECTION ELECTRODE VOLTAGE
OUTPUT PROPER VOLTAGE TO DEFLECTION ELECTRODE
SET DEFLECTION ELECTRODE VOLTAGE TO A CONSTANT PREDETERMINED DEFAULT VALUE
RETURN

FIG. 4

FIG. 5

DEFLECTION VOLTAGE VS. FLOW RATE
FOR CONSTANT CHARACTER HEIGHT



(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number : **0 481 797 A3**

(12) EUROPEAN PATENT APPLICATION

(21) Application number : **91309609.5**

(51) Int. Cl.^{5} : **B41J 2/12**, B41J 2/07

(22) Date of filing : **17.10.91**

(30) Priority : **18.10.90 US 599644**

(43) Date of publication of application :
22.04.92 Bulletin 92/17

(84) Designated Contracting States :
BE CH DE DK FR GB IT LI NL

(88) Date of deferred publication of search report :
16.09.92 Bulletin 92/38

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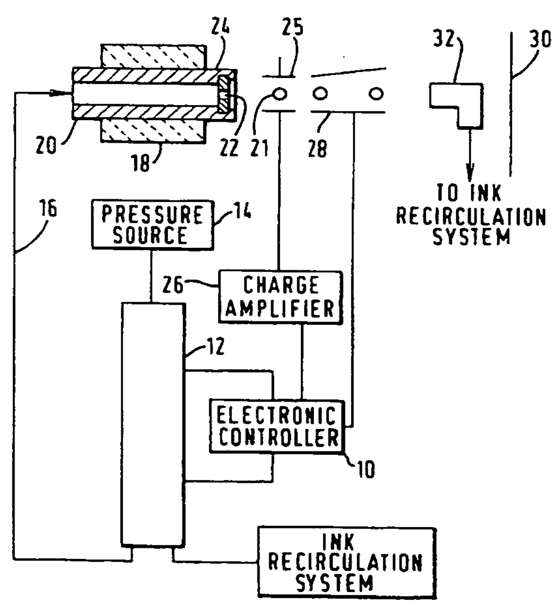
(54) Character height control for drop markers.

(57) A drop marker includes a chamber (12) for electrically conductive marking ink, a pressure source (14) for creating a stream of the ink, and a print head (18) for breaking this stream of ink into drops (21). Charge electrodes (25) impart an electric charge on selected drops, and deflection electrodes (28) create an electric field to control the flight path of the charged drops to mark characters on a substrate (30). The characters are maintained at a desired height by an electronic controller (10) in the form of a system microprocessor which measures a flow parameter of the ink and adjusts the deflection of the ink drops in response to the measured change in the flow parameter. Deflection of the ink drops is adjusted by modifying the deflection voltage applied to deflection electrodes (28) and/or by modifying the electric charge imparted to the selected drops by a charge amplifier (26).

FIG.1



EP 0 481 797 A3

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EP 91 30 9609

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	PATENT ABSTRACTS OF JAPAN vol. 13, no. 71 (M-799)(3419), 17 February 1989; & JP - A - 63272559 (RICOH CO LTD) 10.11.1988 * the whole document * ---	1,7-9, 15	B 41 J 2/12 B 41 J 2/07
A	PATENT ABSTRACTS OF JAPAN vol. 8, no. 201 (M-325)(1638), 14 September 1984; & JP - A - 59091068 (NIPPON DENSHIN DENWA KOSHA) 25.05.1984 * the whole document * ---	1,7-9, 15	
D,A	US-A-4 847 631 (O. NARUSE et al.) * abstract; figure 1 * -----	1-4,13	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)
B 41 J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	03-07-1992	ZOPF K

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